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Broadband multiresonator quantum memory-interface

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In this paper we experimentally demonstrated a broadband scheme of the multiresonator quantum memory-interface. The microwave photonic scheme consists of the system of mini-resonators strongly interacting with a common broadband resonator coupled with the external waveguide. We have implemented the impedance matched quantum storage in this scheme via controllable tuning of the mini-resonator frequencies and coupling of the common resonator with the external waveguide. Proof-of-principal experiment has been demonstrated for broadband microwave pulses when the quantum efficiency of 16.3% was achieved at room temperature. By using the obtained experimental spectroscopic data, the dynamics of the signal retrieval has been simulated and promising results were found for high-Q mini-resonators in microwave and optical frequency ranges. The results pave the way for the experimental implementation of broadband quantum memory-interface with quite high efficiency $\eta > 0.99$ on the basis of modern technologies, including optical quantum memory at room temperature.

The development of the quantum memory (QM) as well as its effective light-media quantum interface are of decisive importance for quantum information technologies[1–3]. Impressive experimental results on the way to the effective optical QM were achieved in the last decade[4–6]. Recently the developed approaches stimulated active studies for the elaboration of the microwave QM which becomes a key element for the creation of multiqubit superconducting quantum computer[7–10]. QM should be able to store many short pulses with the high efficiency[11] and to satisfy very strong requirements of multiqubit quantum processing and error correction procedures[12]. In the practical implementation of long-lived multiqubit QM, it is assumed to satisfy a sufficiently strong and reversible interaction of light/microwave qubits with many[13,14] information carriers, in particular with NV-centers in diamond[15] and rare-earth ions in inorganic crystals[16]. Implementation of sufficiently high quantum efficiently remains main problem in elaboration of the QMs.

One of the promising approaches to constructing a QM is based on the spin/photon echo effect in resonant ensembles of atoms and electron spins[17–20], where a strong coupling of light/microwave photons with quantum electrodynamics cavity mode also plays a crucial role for the effective reversible transfer of quantum information from the flying qubits to the long-lived atomic/spin coherence[7,21–26]. It is possible to increase the quantum efficiency for the broadband interface in this approach via spreading the impedance matching condition to a wider range of working frequencies[22]. However a satisfactory solution of this problem remains unknown for high-Q resonator that strongly limits the spectral width of QM by the overly narrow resonator linewidth[9].

In this work, starting from the AFC (Atomic Frequency Comb) protocol of the photon echo QM[27] in the single mode cavity[21], we showed that quantum memory-interface (QMI) can be efficiently implemented for broadband electromagnetic pulses on a system of high-Q mini-resonators. Herein, we focus on experimental demonstration of this approach in microwave spectral range. To enhance dramatically the interaction with the signal field, we used a set of a small number of mini-resonators coupled to a common broadband resonator that makes it possible to achieve a quite strong interaction of pulse with the mini-resonators which provided highest quantum efficiency of 16.3 % for the broadband storage of microwave pulses. On the basis of the experimental data obtained in the network analyzer measurement, we restored the internal parameters and simulated the observed dynamics of the fabricated multiresonator (MR) scheme with high agreement.

The constructed QMI setup has demonstrated promising technical properties: compactness, low cost and ease of fabrication, which are convenient for controlling the field dynamics and integration of the MR scheme into the microwave circuits of quantum processing. This technical solution allowed us to experimentally investigate the

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